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THE IRON ORES OF SOUTHEASTERN MINNESOTA.*

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ABSTRACT.

Iron ore deposits of greater or lesser extent are scattered over a wide area in southeastern Minnesota. They are limited to the area that is underlain by Paleozoic limestones and dolomites, where they occur as replacements and residual deposits over rocks of Cambrian, Ordovician, Devonian, and Upper Cretaceous age. In Fillmore County the ores attain such thickness that they are of economic value. In the vicinity of Etna, where the glacial drift is thin, test-pits show from 2 to 15 feet of high-grade limonitic ore. The ore lies on Cedar Valley limestone of Devonian age, which it penetrates along joints and bedding planes, and forms linings on solution cavities. Devonian fossils occur in the ore and in the limestone on which it rests.

Most of the ore is soft and earthy and contains from 10 to 30 per cent of siliceous silt, most of which is removed by washing before it is shipped to the blast furnace. Locally the ore is in the form of hard, massive blocks of limonite and goethite. The dry, washed ore averages about 55 per cent iron. About a quarter of a million tons have been shipped and the known reserves are estimated at several million tons.

INTRODUCTION.

IRON ores have been reported from nearly every county in southeastern Minnesota. The early settlers found layers of iron oxide in their dug wells or they plowed up loose chunks while cultivating the land. The earliest geological surveys of the region include references to widely scattered deposits. Shumard [1] reported iron

* Published by permission of the Director of the Minnesota Geological Survey.

[1] Shumard, B. F.: Owen's Geological Survey of Wisconsin, Iowa, and Minnesota, 1852. P. 487.

ore two feet in thickness lying on ferruginous sandstone in the region south of Mankato, and Winchell [2] noted similar deposits near Rapidan. The most extensive deposits were discovered by Mr. C. C. Temple while digging a well in the SE¼, Sec. 8, T102N, R13W, Fillmore County. After throwing out a quan-

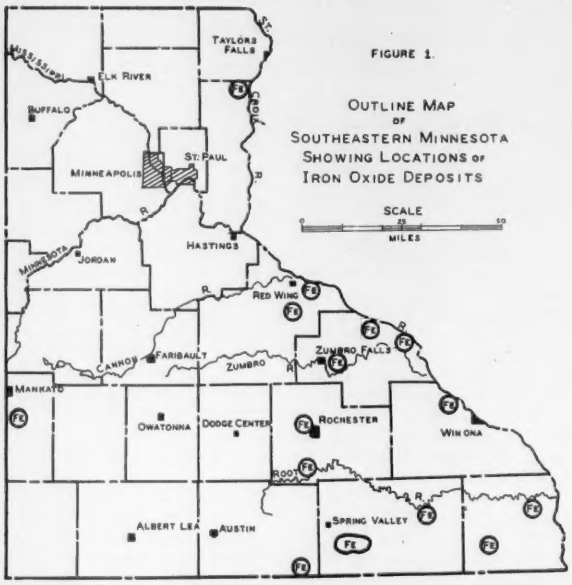

FIGURE 1.

OUTLINE MAP OF SOUTHEASTERN MINNESOTA SHOWING LOCATIONS OF IRON OXIDE DEPOSITS

SCALE
0 25 50
MILES

tity of limestone and "ochreous limonite" he claimed to have drilled 36 feet into iron ore.[3] Similar beds occur in Iowa where they have been mined at Waukon, and they extend also into Wisconsin where they have been utilized on a small scale in a furnace at Spring Valley.

These iron deposits lie on rocks of various ages from Upper Cambrian to Upper Cretaceous, although most of them appear to

[2] Winchell, N. H.: Geological and Natural History Survey of Minnesota. 2nd Ann. Rpt. 1874. Pp. 133–134.

[3] Winchell, N. H.: Geology and Natural History Survey of Minnesota. Vol. I, 1884. P. 310.

be older than the Ostrander gravels (Dakota) of Minnesota in which there are many concretionary iron crusts. At Mankato and Kasota the iron oxides cover the old weathered surface of the Oneota formation and descend into the ancient caves and sinks

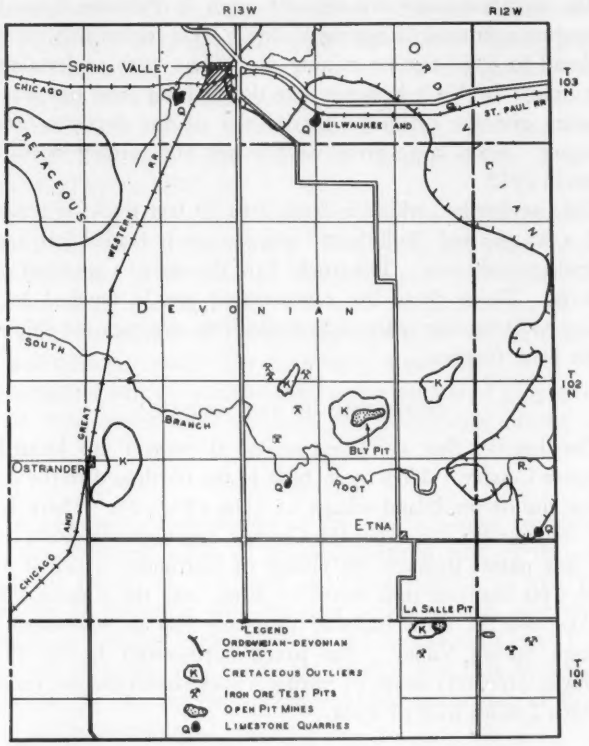

FIG. 2. Map of the ore producing area southeast of Spring Valley.

that were developed during the post-Ordovician-pre-Cretaceous erosion interval, to form crusts on their walls. Here and there the iron-bearing solutions penetrated the siltstone (Blue Earth) floor of the caves and infiltrated the upper part of the Jordan sandstone. At the Osceola bridge in Chisago County 8 feet of

yellow to brown iron ore is separated from the Jordan sandstone by 9 feet of sandy gray shale that may be a remnant of the Blue Earth siltstone. At this place the ore is overlain by an old gray drift sheet, probably Kansan in age.

The most extensive ore deposits occur in Fillmore County in the region southeast of Spring Valley. This region was explored in detail in 1930 but no mining operations were undertaken at that time. In 1941, however, the demand for iron ore was increasing and the economic possibilities of the deposits became apparent. Soon large areas were leased and mining operations began in 1942.

The overburden, which is from 2 to 10 feet thick, is removed with a scraper and "bull-dozer" and the ore is loaded into trucks with electric shovels. The trucks haul the ore to a washing plant at Etna. From there the concentrated ore is trucked to the village of Ostrander where it is loaded into ore cars for shipment to the blast furnace.

GEOGRAPHY OF THE REGION.

The deposits that are being mined at present are located in Fillmore County. They occur both to the north and to the south of the site of the inland village of Etna (Fig. 2). There is no railroad near the mines but the Chicago and Great Western Railway line passes through the village of Ostrander which is four miles west and one mile north of Etna, and the Chicago, Milwaukee and St. Paul Railway Company has an east-west line through Spring Valley. The paved north-south U. S. Trunk Highway (No. 63) south of Spring Valley passes the ore producing area 2 miles west of Etna.

PHYSIOGRAPHY.

The region of Spring Valley is a part of the area designated as "Dissected Till Plains" by Fenneman.[4] These plains are essentially areas of exposed Kansan glacial drift that differ from the Wisconsin drift areas in the stage they have reached in the post-

[4] Fenneman, N. M.: Physiography of Eastern United States. McGraw-Hill Book Co., New York, 1938. P. 588.

glacial erosion cycle. The ore-producing area is a till plain that is submature to mature in its erosion cycle, with a relief of about 100 feet.

The form of the rock surface suggests a flat dome that reaches an elevation of 1,400 feet above sea level in Mower County, from which it declines very gradually in all directions. Spring Valley lies about 20 miles east of the crest of this topographic dome which slopes eastward continuously to the cliffs of the Mississippi Valley where the upland rock surface is about 1,200 feet above sea level. The ores occur where the upland surface is at an elevation of about 1,300 feet.

The principal valleys are those carved by the South Branch of the Root River and its tributaries. Locally the valleys are narrow and canyon-like with cliffs of Devonian and Ordovician limestone bordering the channels. The land forms between the valleys reflect the outlines of the bedrock surface, as the drift is very thin and does not modify the topography appreciably.

The upland surface is covered by a thin mantle of gray to buff silt or loess which tends to mask the inequalities of the rock surface.

STRATIGRAPHY.

The geographic distribution of the ore is almost coextensive with the Paleozoic rocks of the southeastern part of the state. Over this region the ore rests on rocks ranging in age from Cambrian to Devonian with the later stages spilling over on the Cretaceous. In the Etna region the ore lies on the Cedar Valley limestone of Upper Devonian age which is laid bare in both the major pits by the removal of ore. At the north side of Bly pit (Fig. 2) the section is as follows:

SECTION OF BLY OPEN CUT MINE.

	Thickness
Drift	
5. Sand, gravel and boulders	3 feet
Cretaceous	
4. Clay, blue to white, soft, with a few patches of gravel	5 feet
Cretaceous-Devonian	
3. Iron ore, hard vesicular limonite	18 feet
Devonian	
2. Limonite, hard, brown with Devonian fossils	2 feet
1. Limestone, buff to brown, massive, fossiliferous	2 feet
Total	30 feet

Another section a mile east of Etna, in the E. Vanderbosch quarry, Sec. 30-102-12, shows the relationship of the Devonian to the Ordovicion which latter is represented by the Maquoketa shale.

Drift	Thickness
7. Covered to the woods above	3 feet
Devonian (Cedar Valley limestone)	
6. Limestone, dolomitic, buff to yellow, fossiliferous	7 feet
5. Limestone, dolomitic, thick beds, cavernous, gray to buff	10 feet
4. Limestone, dolomitic, massive, gray to buff, fossiliferous	10 feet
Ordovician (Maquoketa shale)	
3. Shale, light gray, and gray limestone beds containing *Lingula iowaensis* and *Dinorthis kankakiensis*	5 feet
2. Shales and limestones, partly covered	15 feet
1. Covered interval to creek level by barn at highway	13 feet

Above the ore the Cretaceous comes in as partly contemporaneous with it but usually showing a distinct break and the deposition of the Ostrander gravels, sands and clays. The type section of this member of the Cretaceous is only a half mile to the South of Ostrander where the following is exposed:

SECTION AT THE CARTHOG GRAVEL PIT
SOUTH END OF THE VILLAGE.

Drift	Thickness
8. Loess and soil	2.0 feet
7. Drift with a few boulders	2.0 feet
Dakota formation	
Ostrander member	
6. Sandstone, brown, coarse, pebbly, iron-stained and iron cemented, very hard	2.5 feet
5. Sand, coarse, and sandy yellow gravel. The pebbles are smooth, rounded to ellipsoidal, pink and white quartz together with subangular flint and chert pebbles about 1/8 to 1/2 inch in diameter	10.0 feet
4. Sandstone, brown, pebbly, hard, and in part a real conglomerate	1.5 feet
3. Gravel, yellow, medium to fine, pebbles of flint and quartz as throughout the formation	1.5 feet
2. Sandstone, brown, coarse, pebbly, poorly cemented	1.0 feet
1. Gravel, yellow stained, poorly sorted, medium to coarse, some pebbles an inch or more in diameter. The pebbles are quartz and flint, and some residual siliceous fossils, even of large size, may be found in these beds. To the level of water in the bottom of pit	5.0 feet

At most of these gravel pits in Fillmore County the gravel and sandstone are underlain by clay and this is probably true in the Carthog pit as suggested by the more or less permanent pool of water in the bottom. The permeation of the gravel by yellow iron stain, the cementing of sands by iron, the general occurrence of the typical "iron conglomerate" and the iron crusts in and on

the Ostrander member suggest that the accumulation of ore continued during at least a part of the Cretaceous.

The contact of the Ordovician and the Devonian is sharp and without indication of iron deposition at any place where it is known in the state. This would seem to suggest that the major part of iron accumulation was post-Devonian and probably connected with the long weathering period between upper Devonian

FIG. 3 (Upper). General view (looking east) of the Bly open pit mine north of Etna. The white layer at the left over the ore is Cretaceous clay and silt with drift above. The road bed in the foreground is on the irregular surface of the Cedar Valley limestone under the ore.

FIG. 4 (Lower). Irregular chunks of hard brown ore in the north wall of the Bly pit. The structure and texture of this type of ore is shown in Figures 5 and 6.

and Dakota. In the section at the Bly Mine, therefore, the iron is designated as belonging in that interval. It is the only record left by that long erosion interval. Where the ore rests on older rocks, such as the Oneota or the Jordan, it is probable that the younger formations were never deposited or they were removed

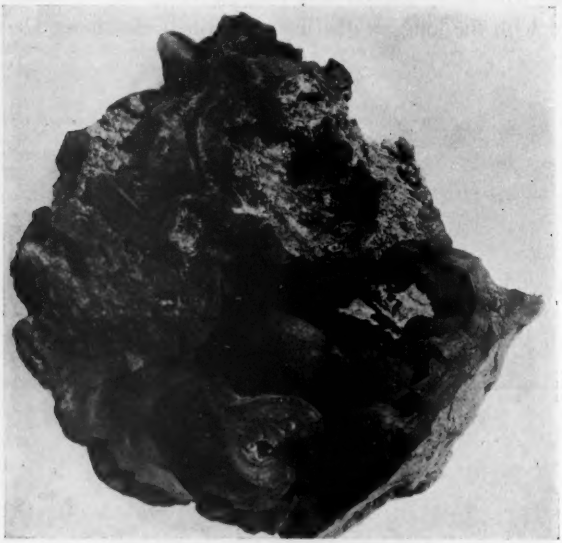

FIG. 5. A nodule of hard brown ore showing the irregular colloform structures of the iron oxides (approx. ¾ natural size).

by the weathering and erosion during the long interval of land conditions that mark the later Paleozoic and much of the Mesozoic eras in the region.

THE ORES.

Occurrence and Composition. The bottom of the ore rests on an uneven surface of limestone (Fig. 3). Numerous masses of limestone extend up nearly to the top of the orebodies. Residual limestone boulders in the ore show all stages of leaching from limestone to residual, calcareous quartz silt. Locally there are

depressions filled with clayey siliceous silt which is partially infiltrated with iron oxide.

Much of the ore is soft and porous with many of the pores partially filled with clay and silt. Irregular concretionary masses with concentric deposition around clayey centers are typical (Fig. 6). The hard ore occurs in solid masses or in honeycombed,

FIG. 6. A piece of hard ore with concentric deposition of iron oxide around a residual fragment of limestone. The smaller pores at the lower left are partially filled with residual siliceous silt derived from limestone fragments that once occupied the spaces (approx. ¾ natural size).

ramifying chunks, boulders, and nodules. The harder portions are light to dark brown in color, usually showing a dull luster on smooth, freshly broken surfaces. Many of the cavities are lined or partially filled with a yellow ocherous powder, or with fine siliceous silt.

Mineralogically the ores are impure mixtures of hydrated oxides of iron containing varying amounts of limonite and goethite. The most undesirable impurities are silica and phos-

phorus. The silica content varies from 5 to 35 per cent, and phosphorus is rarely less than 0.1 per cent and may be as high as 2 per cent. The percentage of alumina is low, indicating that

FIG. 7. Concentric infiltration of iron oxide into the weathered Cedar Valley limestone under the ore at the Bly pit (nearly natural size).

the clayey material in the ore is mainly residual siliceous quartz silt, not aluminum silicate. The analyses in Table 1 are typical.

There is no apparent variation in the composition of the ore with depth. Samples taken 2 feet below the surface may contain as much silica as those from a depth of 10 or 15 feet. At most places there is no sharp contact between ore and rock. The physi-

cal character of the ore determines whether or not the silica can be washed out and the iron oxides concentrated. Where irregular nodules of iron oxides occur in loose, uncemented silt, the silt is washed out readily. However, some of the soft ore is a physical mixture of earthy iron oxides and siliceous silt. Such fine-textured ore tends to be washed away at the concentration plant. In some ore-pockets the silica content of such soft ore is too high to be utilized without concentrating the iron oxides.

TABLE 1.

ANALYSES OF BROWN IRON ORES FROM SOUTHEASTERN MINNESOTA.

Sample No.	Fe	SiO_2	Al_2O_3	P	Mn	S	Ign. Loss.
1	44.77%	19.34%	2.18%	0.408%	0.31%	0.014%	11.80%
2	55.42	5.32	0.34	0.269	0.33	0.002	13.42
3	56.58	4.70	0.24	0.257	0.36	0.002	12.84
4	52.49	8.14	1.78	0.239	0.47	0.004	12.86
5	52.49	9.06	1.16	0.237	0.57	0.007	12.60
6	52.79	10.22	0.74	0.153	0.91	0.007	11.62
7*	55.38	8.06	0.32	0.235	0.51	nd	11.52
8*	49.37	14.24	1.15	0.212	0.59	nd	15.12
9*	41.52	27.06	1.25	0.219	0.41	nd	11.60
10*	35.89	35.86	1.06	0.197	0.63	nd	11.52
11	49.50	15.26	0.65	0.074	nd	0.032	nd
12	56.92	nd	nd	nd	nd	nd	nd
13	57.41	nd	nd	nd	nd	nd	nd
14	52.53	7.20	nd	nd	nd	nd	nd
15	55.70	nd	nd	nd	nd	nd	nd
16	62.26	nd	nd	nd	nd	nd	nd

1. Fine-grained, porous, yellow ore from test pit near south ¼ corner of Sec. 15, T 102N, R 13E.
2. Coarse, well-cemented limonitic ore. Location same as sample 1.
3. Similar to No. 2. Taken from test pit 200 feet farther east.
4. From test pit 10 feet deep that bottomed in Devonian limestone. SE ¼, SE ¼, Sec. 22, T 102N, R 13E.
5. Same pit as No. 4.
6. From test pit on La Salle farm. Sec. 1, T 101N, R 13W.
7. Bly pit, 10 feet below surface. SE ¼, Sec. 23, T 102N, R 13W.
8. Location same as No. 7. From ore pocket 18 feet below the surface.
9. Location same as No. 7. Two feet below the surface.
10. Location same as No. 7. Four feet below surface.
11. From near the village of Goodhue.
12. From near the village of Spring Grove.
13. From near the village of Lanesboro.
14. From near the village of Le Roy.
15. From near the village of Hokah.
16. From near the village of Wabasha.

* Analyses through courtesy of Winston Bros. Company, Minneapolis, Minn.

ORIGIN OF THE ORE.

In view of the fact that much of the ore shows evidence of deposition from solution, it is not a true residual deposit. Some secondary processes of concentration must have contributed to the local accumulation of iron oxides. This conclusion is supported by the fact that the amount of residual iron that could possibly have been furnished by the weathering of the beds of the Cedar Valley limestone would not approach in magnitude the ore deposits at the Bly and La Salle pits. Numerous partial analyses of various facies of the Cedar Valley formations indicate that the average iron content is about 1 per cent. Even by making a liberal estimate of the original thickness of the Devonian strata, their decay would not yield a residual product as thick as the ores in the Spring Valley region.

The structure and texture of the ore give no evidence of bog precipitation and sedimentation. On the other hand, the presence of rounded flint and chert pebbles and boulder-like, silicified stromatoporoid fossils in the ore, suggests some transportation and concentration by surface waters. Underground waters undoubtedly played a major role also.

The concentric tendency of iron oxides is seen in many oxidized mineral deposits, often even in the weathering of pebbles and boulders. Such concentric banding (Fig. 7) is conspicuously developed in the residual limestone boulders in the iron ore and in the limestone strata under the ore at the west end of the Bly pit. During the process of concentration some iron may have been transported as colloidal ferric hydroxides. These permeated the limestone in which they were deposited as typical concentric structure.

As the weathering of the limestone in the surrounding area continued, some of the primary iron carbonate may have been leached out and carried away as a bicarbonate solution. This reaction is more apt to take place at depths where the oxygen supply is exhausted. Such iron-leaching waters, percolating laterally and downward, would encounter fresher limestone which would tend to precipitate the iron carbonate, while calcium car-

bonate would go into solution. Such a process leads to the replacement of limestone by iron carbonate. When erosion later brought the enriched iron carbonate horizon into the zone of active oxidation, the carbonate was altered to limonite and goethite, or to indefinite mixtures of various hydroxides of iron.

Tonnage. The total amount of ore scattered over the known area of distribution in the southeastern part of Minnesota probably amounts to several million tons but the available tonnage may not be much more than a half million tons. This is concentrated chiefly in Fillmore County where the overburden is thin and the localities are readily accessible by truck. Some of the deposits farther to the southeast run higher in silica and are more difficult to utilize. Still others lie on high bluffs and extend back under a heavy overburden. The present activity, if sufficiently prolonged, will probably exhaust the richer deposits.

UNIVERSITY OF MINNESOTA,
MINNEAPOLIS, MINNESOTA,
November 15, 1943.

SCHEELITE VEINS RELATED TO PORPHYRY INTRUSIVES, HOLLINGER MINE.

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ABSTRACT.

The first considerable production of tungsten from the Canadian Shield came from the Hollinger Gold Mine. Scheelite concentrates of exceptionally high grade and purity were milled from localized concentrations of this mineral in the quartz-ankerite and tourmaline-quartz-ankerite veins, which account also for most of the gold production. The position of the scheelite ore in these veins points to a genetic or structural dependence of the vein mineralization on the intrusive quartz porphyries.

INTRODUCTION.

EARLY in 1942 with the fall of the Federated Malay States and Burma, and the isolation of China, the chief sources of tungsten for the United Nations were cut off. It became a problem of vital importance to supply scheelite concentrates to Canada's growing domestic tool steel industry.

The Hollinger management, in cooperation with the Geological Survey of Canada, examined some 300 miles of mine workings for scheelite, with an ultra violet lamp. This paper presents the results of that examination, together with data accumulated by the mine staff in the search for and development of scheelite ore.

Permission for publication was granted by Mr. John Knox, General Manager of the Hollinger Mines, to whom acknowledgments are due. Mr. W. Roy Dunbar, Chief Geologist, and Dr. W. A. Jones offered valuable advice and criticism. Mr. R. W. Vaughan aided with the drafting.

GENERAL GEOLOGY.

The Hollinger Gold Mine is situated at Timmins in the Porcupine mining area of Ontario. The rocks on this property are all

[1] Formerly Geologist, Hollinger Mine.

[2] Formerly Assistant Geologist, Geological Survey of Canada.

pre-Cambrian in age and consist principally of a series of tightly folded Keewatin lavas with thin interbedded carbonaceous sediments, intruded by pipe-like stocks of quartz porphyry. The lavas are of intermediate composition and exhibit a wide variety of textures and structures. The quartz porphyry is an acidic rock and, where fresh, consists of quartz and acid to intermediate feldspar phenocrysts in a felsitic groundmass. Although Graton and McKinstry [3] have referred them to Keewatin time, the porphyries are generally considered to be post-Timiskaming in age

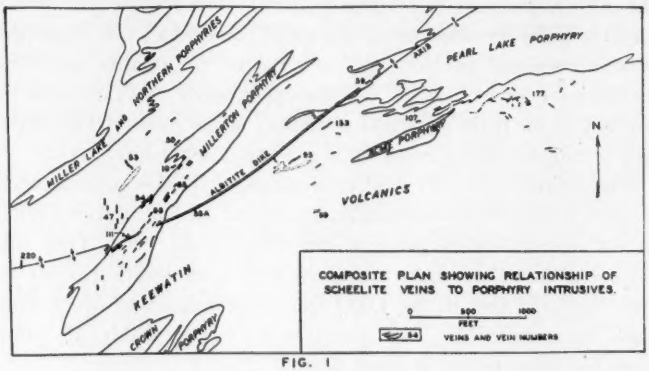

FIG. 1

and genetically related to the massive Algoman quartz monzonite intrusives which border the Porcupine syncline. On the lower levels of the mine an albitite dike, up to 2,000 feet in length and two to ten feet in width, cuts the porphyries, but is itself cut by the gold-and scheelite-bearing veins. Keweenawan diabase dikes, usually less than a foot in width, cross cut the earlier lavas and intrusives.

Figure 1 is a composite plan showing the relation of the porphyry intrusives, the albitite dike, and all major occurrences of scheelite from surface to the 5,150-foot level. The porphyry outlines shown are those of one of the intermediate levels, and all

[3] Graton, L. C., McKinstry, H. E., and Others: Outstanding features of Hollinger geology. Bull., Can. Inst. Min. Met. 26: 1–20, 1933.

major scheelite occurrences above are projected down and all below projected up along the pitch of the porphyry, so that the relationship in plan is not disturbed. This is justified as the pitch and shape of the porphyry bodies is relatively constant. The long axes of the porphyry masses parallel the regional structure, which strikes northeast and southwest.

The main ore zone of the Hollinger mine is a highly altered area about 1,200 feet in width and 5,000 feet in length, which lies along the axial plane of a subsidiary anticline on the north limb of the easterly plunging Porcupine syncline. The albitite dike, which appears to be intruded along the axial plane, does not reach the present erosional surface, nor do some of the smaller porphyry apophyses (dotted lines). On the upper levels the axial zone is marked by the main fault and subsidiary shear zones. The structure is complicated by cross folding along a north-south axis.

The Pearl Lake and Millerton porphyry bodies are intruded along a curved east-west anticlinal axis and have a uniform pitch of 49 degrees in an average direction N. 82° E. They are ellipsoidal pipe-like stocks and show only a moderate increase in cross-sectional area in the 4,000 feet vertical depth to which they have been explored. The porphyry masses probably all came from the same source at great depth.

The rocks have been highly altered by hydrothermal and dynamic metamorphism. A marked schistosity has been developed parallel to the regional axes. The rocks are intensely carbonated and in varying degree sericitized, chloritized, and silicified. Hydrothermal alteration is most intense in the main ore zone.

VEIN TYPES.

Concentrations of scheelite occur in veins associated with the Millerton and Pearl Lake quartz porphyry intrusives. The quartz-ankerite (scheelite) veins of the Millerton porphyry are usually wide veins, measuring up to several feet across, irregular in detail, but generally having a fairly consistent strike. Quartz comprises by far the greater amount of introduced vein material.

Examples (Fig. 1) are the veins situated in the central western part of the porphyry mass. The tourmaline-quartz-ankerite (scheelite) veins associated with the Pearl Lake porphyry are much narrower and more irregular. Examples are the 153 and 177 vein systems in pockets or off noses or apophyses of the Pearl Lake porphyry. All the known scheelite of any importance is associated with the above two vein types. Scheelite was observed in one instance only in the Crown vein system, and its occurrence was almost on a microscopic scale. Scheelite also occurs in minor quantities in veins associated with the Northern porphyries.

The scheelite-bearing veins of the Millerton porphyry have a marked structural relationship to the porphyry mass. All scheelite veins in the west end, with the exception of the 220, are either in porphyry completely, intercept it if parallel because of the steeper vein dip, or cut it at an angle such as the 47 veins. The parallel longitudinal fissures such as 111, 85, 50 and 54 are the biggest veins, the 111 and 85 being in the porphyry completely and the 50 and 54 cutting out from the porphyry hanging wall. The characteristic occurrence of scheelite in the 111 and 85 veins is in small rich pockets, sometimes controlled by wallrock inclusions, whereas that in the 50 and 54 veins is of a more continuous nature and occurs over greater lengths. Work on these and other similar veins shows that they are parallel, en echelon (stepping up and over to the north) fissures, and that most of the scheelite occurs at the base of the veins, as in 111 and 85, or at the porphyry vein contact in such veins as the 50 and 54. The lower a vein can be picked up in or breaking out from the porphyry, the better the chances of finding scheelite. The walls of the porphyry mass have been found to be equally favorable.

Of the Pearl Lake veins the 177 vein system is by far the most important. It differs little from the 153 and 95 vein systems except in having a more complex fracture pattern. The Pearl Lake veins are typically narrow, irregular, en echelon S-shaped gashes, sometimes having a central shear. These scheelite veins are never found in the porphyry but in pockets of the country rock between the porphyry tongues and off noses or apophyses. The

structural relationship is not as marked as with the Millerton porphyry.

At varied distances from the porphyry bodies occur several veins of minor importance which cannot be attached to either of the above types on known structural evidence. Misfits in this group are the 220 and to a lesser extent the 55A veins.

MINERALOGIC TYPES.

Types of scheelite veins have been shown to exist structurally, and the evidence for these types can be enhanced further by mineralogic data. The quartz-ankerite (scheelite) veins of the Millerton porphyry show many striking similarities. The better veins (50 and 54) have continuous leads of scheelite, and these grade into those types having irregular lenses of scheelite (111 and 85), the latter sometimes up to ten feet in length by one in width. All the scheelite is coarse grained, fairly well crystallized, and seldom under half inch fragments. The scheelite of all these veins when in quartz matrix has a characteristic sand color. Locally where the scheelite occurs in the country rock, it may vary to a brown or sometimes orange. Scheelite was one of the first minerals to crystallize but was preceded by quartz. In a slightly later period of fracturing, or perhaps contemporaneously with the scheelite, more quartz and ankerite were introduced along with sparse sulphide and gold. In the 88 vein system small crystals of sphalerite, including the variety ruby sphalerite, are encountered in close proximity to scheelite. The scheelite fragments commonly show a parallel fracture system, these fractures being filled with a glassy transparent quartz. No replacement of the scheelite by other minerals took place in the Millerton veins.

The tourmaline-quartz-ankerite (scheelite) veins associated with the Pearl Lake porphyry are mineralogically distinct from those of the Millerton porphyry. The scheelite occurs as disseminated crystals rather than in lenses or pockets. Abundant tourmaline is characteristic, especially in the 177 vein system, and the scheelite is brighter in color, orange and light reddish brown being common. The deeper scheelite color is thought to be due

to a slightly higher iron content, probably related to the presence of more abundant ankerite. Some scheelite crystals show a marked color zoning, grading out from reddish brown to orange to shades of yellow. Scheelite and apatite were the first minerals to crystallize, being quickly followed and replaced in varying degrees by tourmaline. When subsequently fractured, quartz, ankerite, pyrite and gold were introduced in a second wave of

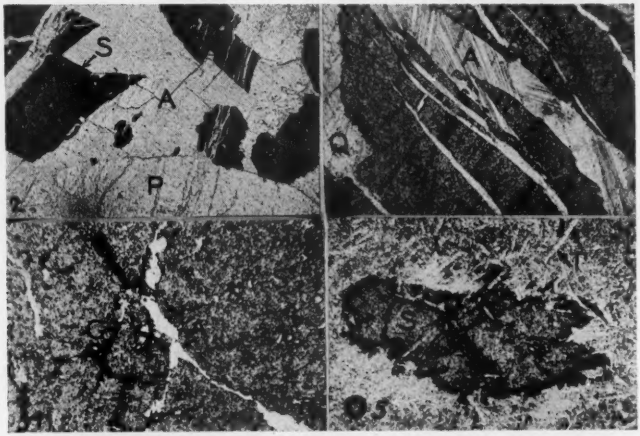

FIG. 2. Photomicrograph from 3 Vein, 100 foot level. Apatite crystal (P), and scheelite crystals with outlines of carbonate cleavage (S), in a groundmass of coarsely crystalline ankerite (A). The fractures in these minerals have been filled with a later generation of carbonate. Transmitted light. $\times 22$.

FIG. 3. Photomicrograph from 95 Vein, 4,100 foot level. Parallel walled fractures in a scheelite crystal (S), filled with polysynthetically twinned gray carbonate, probably ankerite (A). The scheelite is in a groundmass of quartz (Q) and ankerite. Transmitted light, $\times 18$.

FIG. 4. Photomicrograph from 55 Vein, 2,450 foot level. Gold (G) and carbonate (A) introduced into fractures in a scheelite crystal (S). Transmitted light, $\times 34$.

FIG. 5. Photomicrograph from 177 Vein, 3,200 foot level. Fibrous tourmaline needles (T), impregnating and in part replacing a scheelite crystal (S). The original groundmass of carbonate and quartz is now almost entirely replaced. Transmitted light, $\times 25$.

mineralization. Gold occurs sometimes in late fractures of the scheelite. Pyrite is the only common sulphide and is much more abundant than in the Millerton veins.

Analyses of the scheelite show it to be pure calcium tungstate, containing traces of iron but none of either molybdenum or copper. Spectroscopic analysis would be required to determine the iron quantitatively, but the brighter color of the Pearl Lake scheelite over that of the Millerton is believed to be due to a slightly higher iron impurity.

The presence of scheelite veins about each of the Millerton and Pearl Lake porphyries is obvious, but the nature of the relationship is obscure. The vein types exist both structurally and mineralogically about each of the porphyries for over 4,000 vertical feet. The structural control in the Millerton veins is a series of parallel, en echelon, longitudinal fissures, scheelite being concentrated in the porphyry part of the veins and at the porphyry vein contact. Temperature control may play a part in that the scheelite crystallized on entering the vein fractures from the solution channels. From present knowledge structure seems to have played the major role in the Millerton scheelite veins.

In the Pearl Lake area the scheelite veins are commonly gold-bearing, and though structure is probably the main control for the veins as a whole, it does not account for the scheelite being concentrated in that part of the vein closest to the porphyry. Temperature appears to be the dominant factor here. Conversely, veins further away from the porphyry have less scheelite than those close in. In this respect there is a semblance of zoning. The characteristic minerals of both types of veins are concentrated in the primary portions of the veins, but the secondary stages are similar in both. Consequently, zoning cannot be traced past the initial or primary mineralization.

RELATION OF THE SCHEELITE ORE TO THE PORPHYRY INTRUSIVES.

The clear cut association of the porphyry bodies of the main ore zone with the scheelite occurrences is shown in Figure 1. Four

criteria support the idea that the scheelite ore is genetically related to these intrusives:

(1) Scheelite mineralization is commonly associated with acid igneous rocks of the composition of the Porcupine quartz porphyry.

(2) The occurrence of the scheelite ore in veins in the Millerton porphyry (111, 88, 85), veins striking (47, 55A, 53) or dipping (54, 50) into the porphyry, or zoned around small (95, 53) or large (177) porphyry masses, strongly suggests that the porphyries acted as the main channels for the tungsten-bearing solutions. This points to the parent magma of the porphyry as the source of the mineralizing solutions.

(3) Scheelite and gold ore show a semblance of zoning around the porphyry intrusives. Most of the scheelite and only a minor part of the gold ore occur within or at the porphyry contacts. The ratio of gold to scheelite ore rises rapidly away from the center of the porphyry masses. Very little scheelite ore occurs more than 500 feet from the porphyry contact, whereas considerable gold ore is found at greater distances from the contacts. The transition in gold-scheelite ratio is marked by a very abrupt increase in the amount of gold ore in veins outside the porphyry and a rather rapid decrease in amount of scheelite ore once a vein leaves the porphyry.

This relationship is probably due in part to a localized early primary fracturing, closely followed by a high temperature scheelite-quartz mineralization. Subsequent fracturing followed on a larger scale with the primary fracturing as a focal point, succeeded by a secondary wave of mineralization, possibly that giving rise to the main vein system. The semblance of zoning shown by the scheelite and gold distribution is consequently controlled by repeated fracturing during the course of which the mineralizing solutions became successively of lower temperature. This would be especially true of the zone in the Millerton porphyry and the 177 vein system of the Pearl Lake porphyry.

(4) There is a suggestion that the veins of the Pearl Lake type are higher temperature than veins of the Millerton type. Pearl

Lake veins contain tourmaline and apatite and considerable albite-oligoclase feldspar. These minerals, with scheelite, form a typical hydrothermal association. The Millerton veins contain no tourmaline or apatite, and perhaps less feldspar and ankerite. The Pearl Lake porphyry mass is many times larger than the Millerton porphyry mass. High temperature in the veins around the large intrusive, and lower temperature veins around the small intrusive, suggest the genetic relationship of the mineralization to the intrusives. This, in conjunction with structural evidence, points to the conclusion that each porphyry mass has its own characteristic vein system.

ECONOMIC SIGNIFICANCE.

It is doubtful if the scheelite deposits of the Hollinger Mine could be utilized in times of peace in competition with world markets. At prices which existed during the period of production, roughly twice those of peacetime, it is only marginally commercial to open up vein zones in which a concentration of scheelite may be expected, and even this development cost must be borne in part by the gold mining operation.

In most parts of the Canadian Shield the presence of scheelite in quartz veins is an indicator of conditions favoring the formation of gold lodes. It is not considered likely that large scheelite deposits of commercial grade will be found in quartz veins in the pre-Cambrian shield.

TORONTO, ONTARIO,
January 12, 1944.

A LANDSLIDE AREA IN THE LITTLE SALMON RIVER CANYON, IDAHO.

WARREN R. T. WAGNER.[1]

ABSTRACT.

Recent landslides have caused considerable expense to the state of Idaho. The slides wrecked U. S. Highway 95 at several points along the Little Salmon River Canyon, Idaho. Study of the phenomena showed the recent movement to be on the steep front of an ancient, major slide.

INTRODUCTION.

General Statement. About the middle of February 1943 a landslide of major proportions and of considerable economic importance, damaged a section of U. S. Highway 95 along the Little Salmon River Canyon in Idaho County, Idaho. According to Mr. James Reid,[2] District Highway Engineer, cracks first appeared in the highway pavement on or about February 15th. Several days later the roadway suddenly dropped two feet, and at the same time, large masses of rock and soil moved on the hillside above. The road-maintenance crew immediately began repair work and, each day for three months, material was trucked in to keep the roadbed level.

Mr. James Large,[3] Maintenance Foreman, of this section of the highway, states that the rate of lateral movement varied from one to twelve inches in twenty-four hours.

Landslides are common in this area; their scars (Fig. 1) are visible on each side of the river for a considerable number of miles. During the spring of 1941, a previous slide occurred one-half mile north of the present area of movement and, for a period of sixty

[1] Instructor in Geology, School of Mines, University of Idaho.

[2] Personal communication.

[3] Personal communication.

FIG. 1 (Upper). Old landslide scars along the side of the Little Salmon River Canyon, Idaho. Picture taken looking east.

FIG. 2 (Lower). This section of U. S. Highway 95 was abandoned because the debris of the 1941 landslide toe moved down onto the pavement in greater quantities and more rapidly than it could be economically removed.

days, covered the highway faster than it could be cleared; finally, one thousand feet of pavement (Fig. 2) was abandoned.

The field investigation of these two breaks, which occurred in 1941 and 1943 respectively, disclosed that both are located on the steep front of a much older landslide of greater extent.

Throughout the remainder of the paper the slides will be referred to as the 1943 slide, the 1941 slide and the ancient slide.

Location. The Little Salmon River Canyon in west central Idaho heads near New Meadows, Idaho and flows northward through a deep, narrow canyon which it has cut to a junction with the main Salmon River at Riggins, Idaho. The landslide area under consideration is on the west side of this river canyon in Sections 16, 20, 21 and 29, T. 23 N., R. 1 E., Boise Meridian. U. S. Highway 95 follows the canyon bottom from Riggins to New Meadows and the portion of the road, beginning approximately five and one-half miles south of Riggins and continuing for two and one-half to three miles, is built on the toe of the ancient slide at right angles to the direction of original movement.

Field Study. The area was visited by the writer, at the suggestion of Dr. J. D. Forrester of the University of Idaho. The first study was made while enroute to south Idaho on June 10, 1943, for field work with the Idaho Bureau of Mines and Geology. Two subsequent visits to the area have been made, one on August 16th and again on November 14, 1943.

On June 10th, survey-control stations were placed on the gliding plane of the 1943 slide and when these points were observed on August 16th, a vertical displacement of six inches had occurred. However, this movement is thought to have been caused by local settling within the disturbed area and not to movement of the whole slide block. A small, surficial earthflow, possibly caused by autumn rains, destroyed the points sometime between August 16th and November 14th.

TOPOGRAPHY.

Regional. The topography of the region is mountainous; the streams are youthful, their valleys being steep-walled and V-shaped. The Little Salmon River Canyon essentially parallels the

Grand Canyon of the Snake River which lies approximately twenty miles to the west and which is separated from it by the Seven Devils Mountains. The relief is high. Riggins, in the Salmon River Gorge, is at an elevation of approximately seventeen hundred feet above sea level, and the canyon walls rise abruptly to over three thousand feet. He Devil Peak in the Seven Devils Range, fifteen or twenty miles southwest, approaches ten thousand feet in elevation.

Local. The topography of the ancient slide area is typical of that produced by landslide phenomena. The boundaries of this slide can be readily traced since its surface expression is composed of a patchwork of undrained basins and hummocky areas which are in contrast to the ordinary canyon-wall, slope surfaces that have been developed by weathering and erosion. Remnants of the scarp at the head of the old landslide scar are still visible, and the Little Salmon River has cut terraces in the debris of the slide toe. Evidently, when the ancient landslide occurred the canyon was considerably choked with detritus which formed a barrier and impounded the water above it. This influx of hetrogeneous material produced a local base level; the stream consequently began lateral cutting which resulted in the formation of terraces. At the lip of the barrier on the downstream side, the gradient was increased and the stream began headward erosion which entrenched it to the present channel.

GEOLOGY.

The rocks involved in the ancient landslide are weathered mica schists, probably belonging to the Belt series, Algonkian System.

The Little Salmon River has, it seems, carved its canyon along a major fault zone; and later adjustments along this fracture zone caused the ancient slide. When this occurred, the rocks were broken and churned into a jumbled mass of poorly consolidated debris, particularly susceptible to weathering. Thus, there is no definite orientation of rock structure within the slide's mass; however, the nearest outcrops regarded to be in place strike N. 30° E. and dip 20°–40° S.E.

DESCRIPTION OF THE SLIDES.

The Ancient Slide. Since the original movement of the old slide, sufficient time has elapsed for erosion to considerably modify the appearance of the surface features. However, in Figure 3, traces of the scarp (*D–E*) at the head of the slide, the undrained basin and hummocky areas, and the remnants of the toe can be discerned.

FIG. 3. A pen sketch, from photographs and field sketches, of the area occupied by the ancient landslide. View looking northwest. *D–E* trace of scarp at the head of the ancient slide. *A–B* slickensided scarp at the head of the 1943 slide and to the left of *C* is located the 1941 slide.

The ancient slide may be divided into a stable block and an unstable block. When the primary movement occurred, the northern half of the slide had sufficient space in which to spread so that the surface developed as one long, rough, but gently dipping slope and the earth mass involved achieved relative stability. In the southern half of the slide, however, the debris piled into steep slopes near the angle of repose because of the narrowness of the valley into which it moved. Several small earthflows and the larger 1941 and 1943 slides have since occurred on the southern, unstable block.

The 1941 Slide. The 1941 slide developed on the steep front of the ancient, major slide (to left of *C*, Fig. 3) near the northern

limit of the unstable, southern block. According to Sharpe's[4] classification, this slide would undoubtedly come under *earthflow*. It is characterized by some slumping at the head of the flow and the formation of a bulging, broken dome at the toe. As the toe rode across the highway pavement, part of the debris was removed in an unsuccessful attempt to save the roadway, but, because of the tremendous amount of material moving down from above, this stretch of pavement was finally abandoned and a detour constructed around the area. When visited in June of 1943, the lower part, or toe, of the slide was inactive, but some evidences of recent movement were found at the head.

The 1943 Slide. The 1943 slide is near the southern end of the unstable block of the ancient slide. Figure 4 is a photograph of the slide taken from above and across the Little Salmon River; U. S. Highway 95 is in the foreground of the picture and trends N. 20° E. across the toe of the slide. The direction of slide movement has been approximately normal to the roadway. The area of disturbance is 2,000 feet long as measured transversely across the direction of slippage and 1,800 feet from the toe to the scarp at the head.

The slide is typical of the kind that develops in poorly consolidated material. The gliding plane is essentially spoon-shaped and deep-reaching with concave side toward the slip block. Thus, it has the characteristics of slumping as described by Sharpe.[5]

The slump (Fig. 4) may be divided into three distinct parts (1) the basin-like area at the top, (2) the step area, near the center and (3) the toe at the foot of the slope.

(1) The basin-like area was produced when the slide block rotated backward on a more or less horizontal axis parallel to the slope from which it descended. The basin is pronounced to the south end of the slide block but has been destroyed on the north end by continued movement. The basin proper is an undrained depression with the original sod surface warped but unbroken.

[4] Sharpe, C. F.: Landslides and Related Phenomena. Columbia Univ. Press, New York, 1938. Pp. 50–55.

[5] Sharpe, C. F.: Op. cit., pp. 65–74.

The scarp at the head of the basin varies in height from eight feet near point *A*, Figure 3, to sixty feet near point *B*. The vertical displacement near the latter point was greater because part of the water from a spring, situated directly below point *B*, was diverted into the slide by early movement, and the water thoroughly sat-

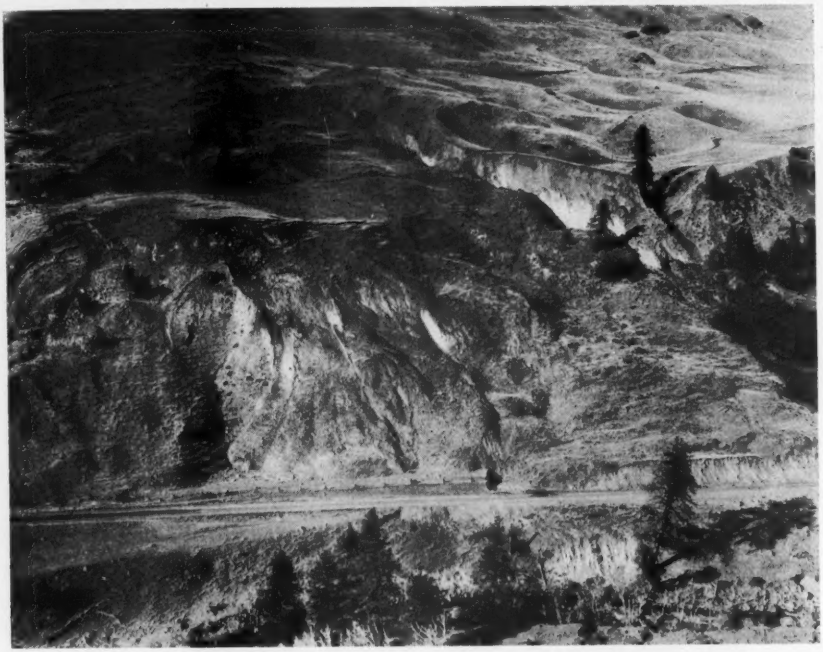

FIG. 4. The 1943 landslide.

urated the already wet and slippery material allowing it to move more freely into the Little Salmon River which in turn carried the material away.

(2) The step area at the central portion of the slide block was caused by differential adjustments between segments of the slide as material below moved toward the toe. The individual steps

are separated from one another by open, vertical fissures which correspond in shape and direction to the main slip plane. These cracks are open to depths of three to ten feet and range in width from one-half to three feet. Where they gape open, the material beneath shows as deep soil underlain by detritus of the ancient slide. The step area gradually disappears into the undisturbed basin floor at the top and into the rough mass of the toe at the bottom.

(3) The toe of the slide is composed of broken, crushed rock, soil, sod and trees shoved into a jumbled mass and does not have the usual folded and overthrust structures described by various writers. The Little Salmon River flows across its front and removes much of the debris as it slips into the river. This fact allows continued movement as no barrier is present to confine the material and to thus allow the load above to fold and overthrust the toe.

CAUSES OF THE PRESENT SLIDES.

The two recent slides were caused by a number of contributing factors. The ancient, major landslide prepared not only the environmental setting of poorly consolidated, weathered debris piled into steep slopes, but also the topography made up of hummocky areas and undrained basins. Thus, the topography and the material were conducive to catching and holding quantities of water from the heavy spring rains and melting snows of the higher slopes. These factors coupled with the slippery, micaceous character of the original bed rock produced perfect conditions for the occurrence of secondary landslides.

ECONOMIC CONSIDERATIONS.

The damage caused by the recent slips was considerable. U. S. Highway 95, a main, arterial route, was badly broken at two points, a ranch house was necessarily abandoned, and one and one-half miles of semi-improved ranch-road had to be relocated.

The Idaho Bureau of Highways spent $1,000 in an unsuccess-

ful attempt to control the 1941 break and preserve the highway before a detour was finally constructed around it. Although the detour moved the roadbed away from the encroaching debris, the problem has not been completely solved since the road is too crooked and slow for a main travel route. Generalized calculations indicate that more than five million cubic yards of earth and rock would have to be moved in order to permanently restore the roadbed to its original position.

The 1943 landslide presents a different problem in that no space is available in which to build a detour; therefore, the roadway has to be kept passable across the slowly moving detritus by continuous repair work. To date it has cost $2,000 to maintain a five hundred foot section in usable state. At the present writing the pavement is in good repair, but the spring rains and thaw undoubtedly will activate the mass and disrupt the road again.

In the writer's opinion, relocation of the two and one-half to three miles of roadway which crosses the ancient landslide is the only permanent solution to the problem, as a whole. This could be accomplished by constructing a new highway along the east side of the Little Salmon River. Two bridges and much rock work would be necessary in this case; yet, over a period of years this probably would be more economical than annually maintaining the highway over the sliding area. A more detailed study should be carried on along this suggested route, however, as there are indications of old landslides on the east side of the river also.

SUMMARY.

In the Little Salmon River Canyon of west central Idaho landslides have considerably damaged the U. S. Highway 95 in the past three years. Study of the slides shows them to have occurred in the unconsolidated, detrital material of an ancient, major landslide. In an attempt to control these landslides the state has expended several thousand dollars, and the indications are that the most recent break, because of its size and location, will continue to cause traffic interruptions and continued expense unless the highway is relocated.

ACKNOWLEDGMENTS.

The writer wishes to express his appreciation to Mr. James Reid, District Engineer, and Mr. James Large, Maintenance Foreman, for details concerning the movements of the slide and estimates on costs of repairs, also to Professor J. D. Forrester for suggestions while the article was in preparation.

MOSCOW, IDAHO,
January 11, 1944.

DISCUSSION AND COMMUNICATIONS

DIP AND STRIKE FROM THREE NOT PARALLEL DRILL CORES LACKING KEY BEDS.

Dear Sir: Professor Bucher has performed a useful service to geologists in pointing out a simple graphic solution of this problem by means of the stereographic projection.[1] It is the purpose of this note to show that the solution offered by Professor Bucher, though correct, is somewhat more complicated than is required by the problem.

On pages 654–656 of Bucher's article, he develops a procedure for drawing the circles representing the locus of the poles of all the bedding planes which make the required angle with the drill core. Bucher's procedure involves rotation of the drill hole through 90°, and the construction of two circles. This is unnecessary, as all the data required for construction of both the circle at $90° + \beta$ and that at $90° - \beta$ can be read directly from the Wulff net.

Perhaps this can best be visualized by assuming, in the first instance, a vertical drill hole (Fig. 1). The vertical drill hole appears at the center of the projection. The bedding planes are assumed to pass through the center of the reference sphere and the family of their poles will thus form a double cone with the vertex at the center of the reference sphere and with a radius equal to the complement of the angle between the drill axis and the bedding plane. In the illustration, this angle is 60°, so that the radius of the circle marking the intersection of the cone with the sphere is 30°. As long as the radius of this cone is less than the depression angle of the drill hole, the circle lies wholly in the lower

[1] Bucher, W. H.: Dip and strike from three not parallel drill cores lacking key beds. ECON. GEOL. 38: 648–657, 1943.

hemisphere and hence will project on the plane of projection as a complete circle.

Now imagine the drill hole (and the symmetrical double cone of poles) to be tilted away from the vertical. Until the tilting

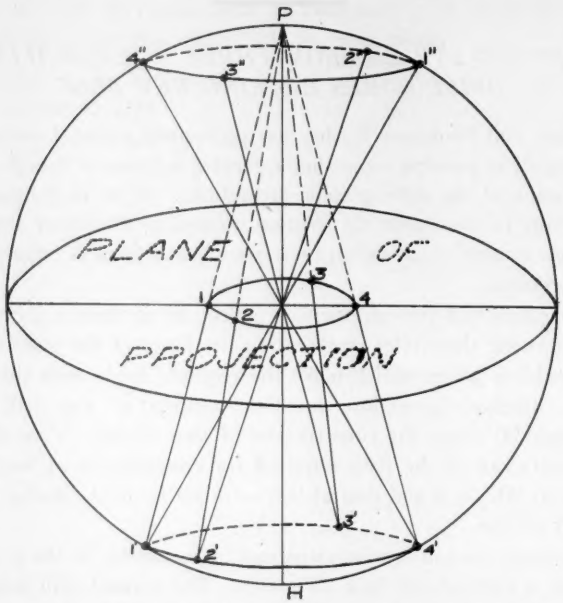

FIG. 1. Diagram illustrating the double cone representing the locus of the poles to all planes making an angle of 60° with a vertical drill hole. The diagram illustrates that the poles to all possible planes making an angle of 60° with the drill hole H lie on a double cone with its vertex at the center of the reference sphere. Inasmuch as only the lower hemisphere is considered in the projection, the diameters 1′–1″, 2′–2″, 3′–3″, 4′–4″ are projected to the points 1, 2, 3, 4, respectively.

reaches an angle of 60° (depression angle of the drill hole equals 30°), there is no essential difference in the projection of the cone, though of course the diameter of the actual circle portraying it in the projection increases owing to the properties of the projection. When, however, the drill hole reaches a depression angle of 30°,

the circle becomes tangent to the edge of the projection. At this instant, the generating vector of the cone that has not hitherto been plotted because it is in the upper hemisphere of the reference sphere becomes parallel to and lies in the plane of projection. The

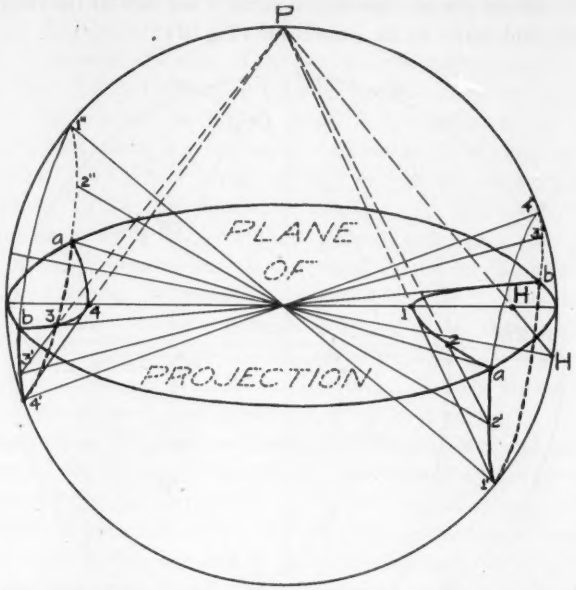

FIG. 2. Diagram illustrating relations with drill hole having depression angle of 10°, angle between core axis and bedding 60°. The points 1, 2, 3, 4 represent the projections of the poles indicated by 1′–1″, 2′–2″, 3′–3″, and 4′–4″ respectively. It can be seen that the points marked a and b (on opposite ends of diameters marking intersections of the circles and the projection plane) represent the same points, respectively. It is also apparent that the depression angle of 4′ is equal to the apical angle of the cone minus the depression angle of the drill hole.

pole of the plane represented can equally well be plotted at the point of tangency of the projected circle or at the opposite diameter of the projection. Further tilting (further flattening of the drill hole) leads to cutting out part of the circle which has hitherto embraced the projected positions of all possible poles having the

required angular relation to the drill hole, so that the circle is truncated. But, as each successive point is cut out from the original circle, it can be imagined to be instantaneously transferred to the opposite diameter of the projection, so that all possible poles are always represented in the lower half of the reference sphere, and hence in the projection (Fig. 2)..

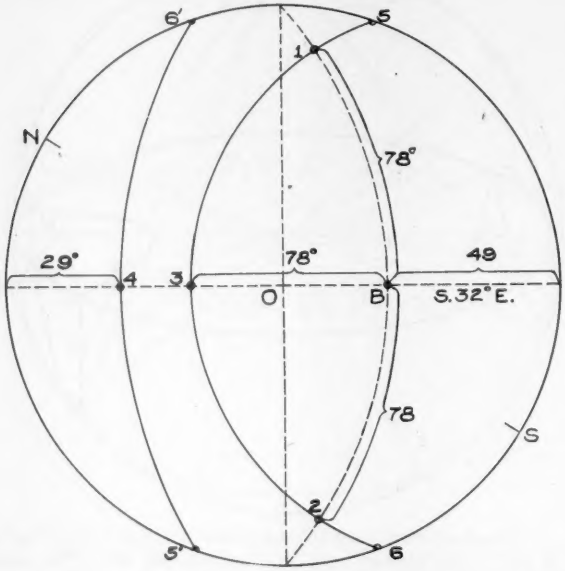

FIG. 3.

This imaginary procedure enables one to visualize a considerable short cut in Bucher's construction. Figure 3 represents the same data as Fig. 5, p. 655, of Bucher's article. The point B represents the projection of the drill hole, S. 32° E., depression angle 49°. As the angle between the drill hole and the plane of the bedding is 12°, the angle between the drill hole and the normal to the bedding is 90°–12°, or 78°. In order to construct the two arcs that together constitute the locus of all possible points having this relation to the drill hole it is unnecessary to rotate the drill

hole. Merely count 78° along all the great circles passing through B, each point thus determined necessarily being on the required locus. The points 1 and 2 are determined by counting along the meridians of the projection, the point 3 by counting west along the equator. These three points determine one arc of the locus, and it is then drawn in as the curve 6, 2, 3, 1, 5. On counting east along the equator, the edge of the projection is reached at 49°, i.e. before the required 78° have been traversed. However, inspection of the relations in Fig. 2 shows that a radius of the reference sphere having a given angle of elevation above the plane of projection (and which hence can not be plotted) is as validly represented by the opposite end of the diameter, which of course has the same angle of depression. Accordingly, enter the west edge of the projection and count toward the center the required additional number of degrees to make 78, viz. 29°. This determines point 4. Further reference to Fig. 2 shows that points 5 and 6 can as well be plotted at the opposite ends of the diameters of the projection—at 5′ and 6′ respectively. Thus the second part of the locus shown by the curve 5′, 4, 6′ can be drawn.

Inasmuch as the projected position of the drill hole lies on the equator of the projection during the construction, advantage may be taken of the symmetry of the net to save still other steps. For example, the points 5′ and 6′ are obviously symmetrically situated with respect to the N–S line of the projection and can be plotted by inspection after 5 and 6 are determined. Again, a check is furnished on the accuracy of construction of the parts of the small circles 6, 2, 3, 1, 5 and 5′, 4, 6′ by the fact that the center of each of these circles should fall upon the equator (or the equator extended) of the projection. This check is, of course, also available in Bucher's construction.

The procedure outlined in this note eliminates the necessity of rotating the drill hole 90° as Bucher suggests and requires the construction of one less circle, thus lessening the likelihood of errors in construction.

JAMES GILLULY.

UNIVERSITY OF CALIFORNIA,
LOS ANGELES, CALIFORNIA,
March 31, 1944.

REVIEWS*

Military Maps and Air Photographs. By A. K. LOBECK AND W. J. TELLINGTON. Pp. x + 256; profusely illustrated. McGraw-Hill, New York, 1944. Price, $3.50.

American geologists have long endeavored to impress military leaders with the value of geology in warfare beyond its application in water supply and topography. The publication of this book, although not produced through the War Department, is further indication that the importance of geology in military campaigns is being appreciated. In the preface, the authors point out this additional application of geology by stressing "—that there is much more to the use of maps than map reading alone and that a large amount of useful information about a region can be gained from—map interpretation." In addition to the use of maps in determining distances and elevations and presence of cultural features, "—it is possible to make correct inferences regarding the rocks, soil and disposition of topographic forms, and even to make a shrewd guess about the nature of the adjacent regions not appearing on the map in hand." The authors urge the development of proficiency through practice in map use as well as thorough knowledge of map symbols and a development of interpretive ability with regard to the great variety of contour groupings or "patterns."

Military Maps and Air Photographs has a page size of 8½" × 11". The value of the large page size is evident when the reader views the numerous full-page topographic examples and excellent air photos. The book is divided into seven sections, Basic Map Reading, Elementary Problems and Methods, Topographic Forms, Advanced Map Reading, Landscape Types, Air Photographs, and Problems. J. K. Wright of the American Geographical Society has written an interesting introduction for the book in which he outlines the history of topographic maps. The presence of a great number of sample maps, photographs, and classic "Lobeck diagrams" points out the belief of the authors in training through illustration, and the section on problems (with answers) exemplifies their desire to afford practice of the principles outlined. The reviewer wishes to stress that this book has a usefulness beyond that suggested in its title. Its organization

* Books noted under *Reviews* and *Books Received* may be ordered through the Economic Geology Bookshop, M. M. Leighton, Urbana, Ill., but orders for official reports and single copies of Journals should be sent directly to their publishers.

and content are such that the book should prove an excellent text and indispensible reference for classes in elementary geology, cartography, geomorphology, and civil engineering. The subject matter is discussed in a lucid manner although for some topics the material appears to be scattered throughout various parts of the book. The text figures are not numbered and the reader may find some difficulty in locating the figure referred to in the discussion.

Professor Lobeck has spent considerable time at West Point since the outbreak of the war lecturing in map interpretation, although he is still active at Columbia. Captain Tellington is instructor in the Department of Military Topography and Graphics at West Point.

RALPH E. DIGMAN.

Geology in the Service of Man. By W. G. FEARNSIDES AND O. M. B. BULMAN. Pp. 158; Figs. 36. Pelican Books, Pub. by Penguin Books Ltd., West Drayton, Middlesex, 1944.

Here is further evidence of the desire of leading English geologists to present their science to the British layman in an interesting and thorough, yet "palatable" manner. Even though printed on poor grade paper with paper cover these Pelican Books have been well received. *Geology in the Service of Man* consists of two parts: 1, The Nature of the Evidence: An Introduction to the Principles of Geology, and 2, Some Applications of Geology. In Part 2 the discussion covers the subjects of water supply, soils, petroleum, mineral and chemical supplies, and gemstones. A tabular classification (genetic) of igneous and sedimentary rocks is appended.

The senior author is Sorby Professor of Geology in the University of Sheffield and is now the president of the Geological Society of London. His approach in this volume has been that of the economic and structural geologist. Dr. Bulman is Lecturer at Cambridge and is an editor of the *Geological Magazine*. His interests have remained essentially zoological. The collaboration of these two men in this volume has been most successful and the results of their efforts should be of considerable interest to the American as well as the British layman who wishes to cultivate an interest in geology.

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RALPH E. DIGMAN.

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Avulso 49. **O Codigo de Minas e o incremento da Mineracao no Brazil em 1941.** JOSE ALVES. 1943.

Avulso 50. **Cromo em Piui, Estado de Minas Gerais.** H. C. A. DE SOUZA. Pp. 30; Figs. 8; Pls. 6. 1943.

Avulso 51. **Informacoes Sobre Aparelhos e Dispositivos Para Extracao de Ouro de Aluviao.** DJALMA GUIMARAES. Pp. 20; Figs. 14. 1942.

Avulso 53. **Mica na Regiao de St. Maria do Suassui, Estado de Minas Gerais.** T. G. MURDOCK AND CHARLES E. HUNTER. Pp. 27; Pls. 2. 1944.

Avulso 54. **Mica no Estado de Sao Paulo.** THOMAS G. MURDOCK. Pp. 30. Fig. 1. 1944.

Avulso 55. **Cristal de Rocha, No Estado do Espirito Santo.** FREDERICK L. KNOUSE. Pp. 16; Figs. 2; Pls. 4. 1944.

Avulso 56. **Abecedario do Prospetor de Mica.** DONALD D. SMYTHE. Pp. 22; Figs. 5. 1944.

Boletim 55. **Zirconio em Pocos de Caldas.** EMILIO A. TEIXEIRA. Pp. 63; Figs. 5; Pls. 11. 1943.

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Boletim 57. **Relatorio de Diretoria, 1940.** OCTAVIO BARBOSA AND GLYCON DE PAIVA. Pp. 95; Figs. 6. 1943.

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Publicacion XVII. **Estudio Geologico- Economico del Yacimiento de Mineral de Antimonio (Estibina), de la Mina "Victoria", Alti de Chorrillos, Departamento de La Poma, Provincia de Salta, Puna de Atacama.** LUCIANO R. CATALANO. Pp. 31; Figs. 24.

Publicacion XVIII. **El Preensenadense es un Horizonte Geologico o una Facies.** ALFREDO CASTELLANOS. Pp. 84; Figs. 19.

Publicacion XIX. **Geologia Economica del Yacimiento de Plomo, Plata, Oro y Zinc, de las Minas "Emilia", "Dolin" y "Flammarion", Territorio Nacional de los Andes.** LUCIANO R. CATALANO. Pp. 33; Figs. 15.

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Ano VI, No. 3 y 4. **Geologia Economica Argentina.** T. G. CASTELLANOS. Pp. 23; Fig. 1.

Reconcocimiento Geologico de la Parte Central de la Sierra Norte de Cordoba. T. G. CASTELLANOS. Pp. 57; Figs. 36.

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Geological Survey of British Guiana. Georgetown, Demerara.

Bull. 16. **The Geology and Geography of the Towakaima Region, Upper Barama Valley, North West District.** D. W. BISHOPP. Pp. 28; Geol. Map. 1941. Price, 24 cents.

Bull. 17. **Report on the Geology, Gold and Diamond Deposits of the Awarapari—Issineru—Putareng Area, Upper Mazaruni River.** D. A. BRYN DAVIES. Pp. 30; Figs. 17; Pl. 1; Geol. Map. 1941. Price, 24 cents.

Bull. 18. **Report on the Geology of the Waikuri District, Cuyuni River.** S. BRACEWELL. Pp. 16; Geol. Map. 1942. Price, 24 cents.

Bull. 19. **Report on the Area Between Arakaka and Kokerit, North West District.** S. BRACEWELL. Pp. 32; Pls. 4; Geol. Map. 1942. Price, 24 cents.

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No. 2. **Geologie et Richesses Minerales de la region d'Erzincan.** V. STCHEPINSKY. Pp. 65; Pls. 5; Geol. Map. Serie C: Monographies. 1941.

No. 6. **Le Dispositif Geologique du Secteur Petrolifere du Bassin se Boyabat.** M. M. BLUMENTHAL. Pp. 62; Figs. 7. Serie A: Communications. 1942.

No. 7. **Contribution a l'etude de la Faune Cretacee de la Turquie.** V. STCHEPINSKY. Pp. 68; Fig. 1; Pls. 7. Serie B: Memoires. 1942.

No. 8. **Etude Paleontologique de Quelques Gisements du Lias d' Anatolie.** GALIB OTKUN. Pp. 41; Figs. 7; Pls. 4. Serie B: Memoires. 1942.

Extrait, "M. T. A." No. 1/29. **Quelgues Gites de Chromite en Forme de Filons et Leur Genese.** V. KOVENKO. Pp. 40; Figs. 2; Pls. 2. 1943.

Extrait, "M. T. A" No. 2/30. **Region ded Mines de Pyrite Cuivreuse (Vilayet de Giresun).** V. KOVENKO. Pp. 29; Figs. 9. 1943.

Records of Department of Mineralogy. D. N. WADIA. Pp. 38; Figs. 15. Professional Paper Paper No. 1. Columbo, Ceylon, 1943. *Professional Paper No. 1 of the Ceylon Dep't of Mineralogy is the first of a new series of publications of the geology of Ceylon. Four articles are included in this initial number: 1, Rare Earth Minerals of Ceylon; 2, A Brief Account of the Graphite Deposits of Ceylon; 3, The Three Superposed Peneplains of Ceylon; and 4, Bibliography of the Geology of Ceylon. Dr. Wadia was appointed Government Mineralogist of Ceylon in 1939, having distinguished himself for his work on the Geological Survey of India.*

Esquisse Geologique de l'Afrique Equatoriale Francaise. PIERRE LEGOUX AND VICTOR HOURCQ. Pp. 93; Bulletin 1. Du Service des Mines. French Equatorial Africa. Le Caire, 1943. *Here is another important milestone in the geology of Africa. This bulletin has been in preparation, under severe difficulties, since June, 1940. The text is in two parts, with 12 chapters, and is accompanied by an excellent colored geologic map with a scale of 1/3,500,000. The authors of this publication are to be congratulated for this valuable work.*

Service des Mines. Dakar, French West Africa.

Bull. 4. **Esquisse Geologique de l'Afrique Occidentale Francaise.** PIERRE LEQOUX. Pp. 134; Figs. 16; Geologic Map, in color, 1/5,000,000. 1939.

Bull. 5. **Description Petrographique et Etude Geologique de la Region Forestiere de la Guinee Francaise.** A. OBERMULLER. Pp. 207; Figs. 21; Pls. 21; Carte Geologique Generale de la Region Forestiere de la Guinee Francaise, Scale 1/550,000; Carte Geologique de la Chaine Metamorphique de la Haute Guinee Francaise, Scale 1/250,000. 1941.

SOCIETY OF ECONOMIC GEOLOGISTS

NATIONAL ROSTER OF SCIENTIFIC AND SPECIALIZED PERSONNEL.

The Society recently received a communication from the Director of the National Roster of Scientific and Specialized Personnel calling attention to the desirability of registering with the Roster persons with professional and scientific qualifications, such as young engineers, geologists, chemists, and the like. This notice is of particular importance now because so many younger geologists are being inducted from technical work into the Armed Forces. The assignment of young geologists to military branches and the action of local draft boards in response to appeals for deferment have to be based in large part upon the standing of such young men as technical or scientific workers.

The Roster's records are sufficiently detailed to favor the careful selection of persons having special professional qualifications in practically every field of geology. As a civilian agency of the government the Roster has no responsibility for the assignment of its registrants, once they are within the armed forces. The Roster does, however, furnish to the Army and Navy, upon their request, advice concerning the specialized training and qualifications of those Roster registrants who are to be inducted. Such information thus serves as an aid in determining the initial military assignment of a particular individual.

The Roster has been increasingly successful in building up a detailed file of the nation's scientists and technical men. The Council of the Society of Economic Geologists at its February, 1944, meeting therefore agreed to urge employers to request aid from the Roster in securing the services of economic geologists. Among other advantages resulting from this practice, such inquiries by employers apparently afford the *only means* for estimating the national shortage of economic geologists. The Council of the Society also hereby urges economic geologists, whatever their age, degree of advancement, and specialized field, to register with the Roster. All communications should be addressed to the National Roster of Scientific and Specialized Personnel, Washington 25, D. C.

BENJAMIN LEROY MILLER.

1874–1944.

Benjamin LeRoy Miller, 37 years Professor of Geology at Lehigh University, Bethlehem, Pa., a charter member of the Society of Economic Geologists, died of a heart attack at the University March 23, 1944, a few days after returning from commercial work in Florida.

His last year before compulsory retirement from the teaching staff at 70 was spent on leave that he might conduct courses at Princeton in the fall and devote more time to his consulting work.

Miller was an enthusiastic traveler. Twice he went around the world, over which his students are so widely distributed. Vacations commonly were spent in various parts of the world visiting mining regions, in Europe, South America, Alaska, Japan, Mexico, anywhere that promised to broaden his knowledge of economic geology. For that was his interest, as evidenced by his writings. One of his larger works was the Mineral Deposits of South America, with J. T. Singewald, Jr. as coauthor. Another is the 700-page Limestones of Pennsylvania, published by the State Survey, in which some of the material was derived from his long connection as consulting geologist with portland cement companies.

Born in Kansas April 23, 1874, graduating A.B. from The University of Kansas in 1897, and earning his Ph.D. at Johns Hopkins in 1903, he was associate professor of geology at Bryn Mawr 1903–07 and professor of geology at Lehigh University from 1907 until his death. The degree of Doctor of Science was conferred upon him by Moravian College, Bethlehem, Pa., in 1941.

Beginning as an assistant on Kansas University Geological Survey in 1906, he successively served on the Maryland, United States, and Pennsylvania Geological Surveys. Voluminous reports on the Geology and Mineral Resources of Lehigh and Northampton Counties, in which he had spent so many years, are a monument to his State service. His publications on limestone, portland cement, graphite, and other non-metallic products show a wide variety of interest.

Miller was a member of several scientific societies, including the Geological Society of America, the American Institute of Mining and Metallurgical Engineers (of whose Industrial Minerals Division he was Chairman in 1942), the Pennsylvania Academy of Science (of which he was the second President), the Mineralogical Society of America, and the Geological Society of London. He was also a member of the Religious Society of Friends. He is survived by a daughter—Ruth Meredith (Mrs. Otto H. Spillman, Bethlehem) and a son—Ralph LeRoy Miller, of the geology faculty of Columbia University and U. S. Geological Survey.

Professor Miller's casket rests in a groove in the limestone that he knew so well.

R. W. Stone and G. H. Ashley.

SCIENTIFIC NOTES AND NEWS

G. F. LOUGHLIN who has been Chief Geologist of the U. S. Geological Survey for the past nine years, has been appointed Special Scientist of the Survey that he may devote himself to research on special problems in the field of economic geology. W. H. BRADLEY in charge of the Military Geology unit of the Geologic Branch for the past two years has been appointed Chief Geologist.

W. H. EMMONS who for more than 30 years has been head of the geology department at the University of Minnesota, and C. R. STAUFFER, paleontologist, were retired on June 30. G. A. THIEL has been appointed chairman of the department and F. F. GROUT will take over the directorship of the Minnesota Geological Survey.

J. K. GUSTAFSON, recently on the staff of Metals Reserve Co., is now with the Newmont Mining Corp. and at present is making a geologic study of the Magma Copper Co. mine at Superior, Arizona.

A. L. DUTOIT writes from Cape Town that E. D. MOUNTAIN is president of the Geological Society of S. Africa, T. W. GEVERS has been awarded the Draper Memorial Medal by the Society, and that F. DIXEY has left Northern Rhodesia to become director of the Geological Survey of Nigeria.

Attention of young geologists is directed to the following:

The John Simon Guggenheim Memorial Foundation announces that the Trustees of the Foundation have appropriated $200,000 for post-Service Fellowships as an addition to the usual Fellowship budgets. These funds will be used to grant Fellowships to young scholars who are serving the Nation in the Armed and other Governmental Services, including those doing war research under contracts made by the Office of Scientific Research and Development and similar agencies. The post-Service Fellowships will be granted upon the same basis as the other Fellowships of the Foundation, to persons who have demonstrated unusual capacity for research. They will be granted before the end of the war and will be made available for the use of the recipients whenever they are discharged from service. Five such Fellowships have already been awarded.

Other applications for the Fellowships of the Foundation are due on or before October 15 of each year but no final date has been fixed for the receipt of applications for the Foundation's post-Service Fellowships. Persons who wish to apply for post-Service Fellowships are urged to file their applications as soon as possible.

Address Henry Allen Moe, Secretary General, The John Simon Guggenheim Memorial Foundation, 551 Fifth Avenue, New York City.